

Characterizing the diffuse neutrino observations through multi-messenger studies



Antonio Marinelli for the KM₃NeT collaboration
(Università Federico II, INFN Napoli, INAF OAC)

Multimessenger astronomy in the Einstein Telescope Era

Padova 10-12/02/2026

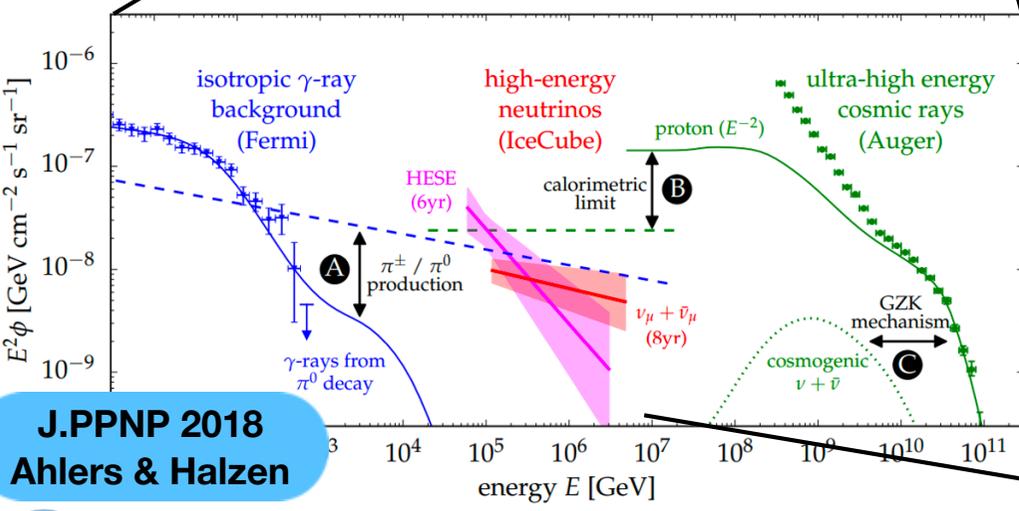
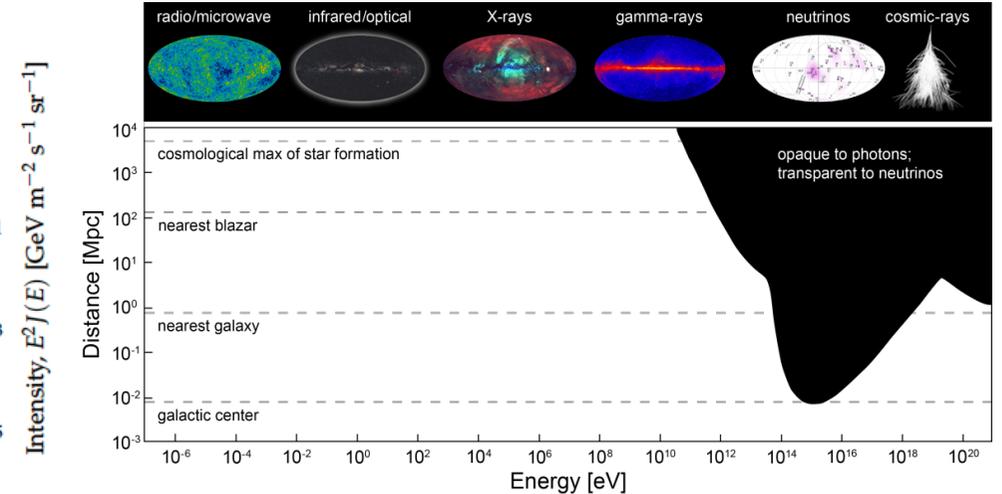
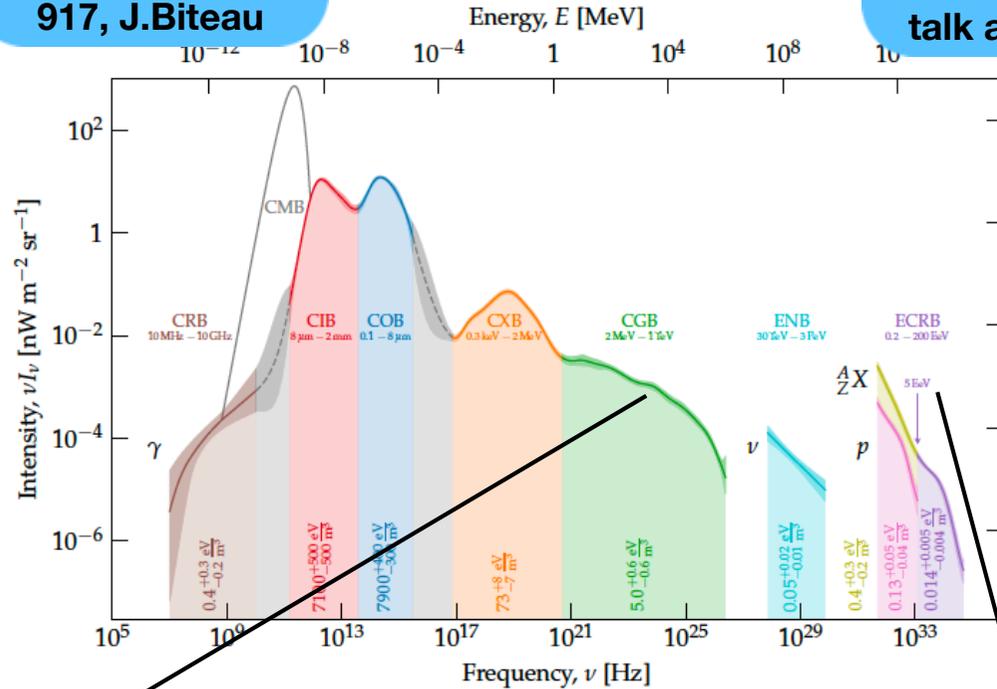
 PalazzodellaSalute

Multi-messenger pic: ν , γ , CR, GW connections

PoS (ICRC2025)
917, J.Biteau

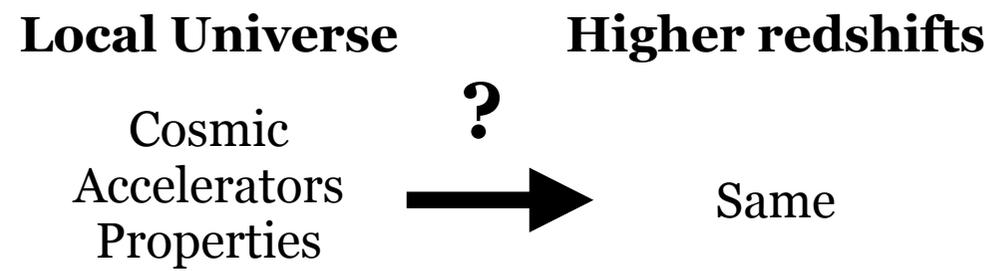
From my rapporteur
talk at ICRC 2025

IceCube
Website



J.PPNP 2018
Ahlers & Halzen

At VHE different horizons for γ , ν , CR, GW:
This impose extrapolation of properties
obtained for local Universe to higher redshift

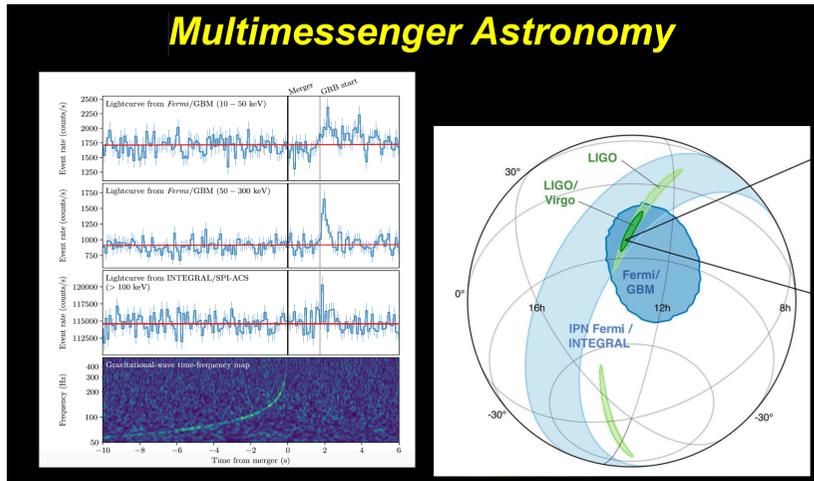


Comparing different energy ranges not always
straightforward



Multi-messenger picture

- Is it a MM breakthrough limited to local Universe?
Search for cases like Supernova 87A.... Or GW170817



LV Collaboration
Phys. Rev. Lett. 119 2017

Still only one Multi-messenger observation in 2017 GW/ γ , No ν counterpart till date



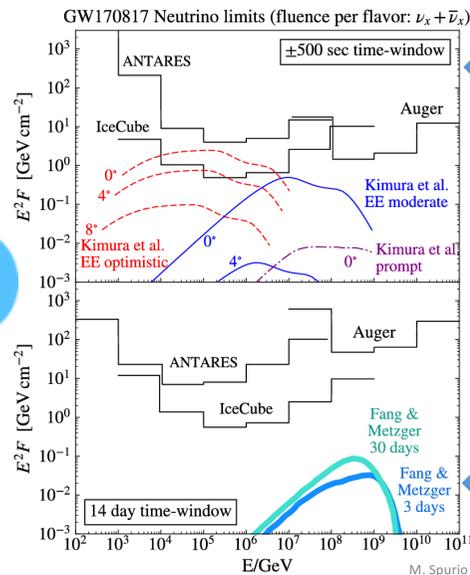
Neutrino Follow-up of GW170817

ANTARES, IceCube, Pierre Auger, LIGO/Virgo. [ApJL 850 L35 \(2017\)](#)

More GW/ γ positive
Follow ups expected during the
Next LVK run O5

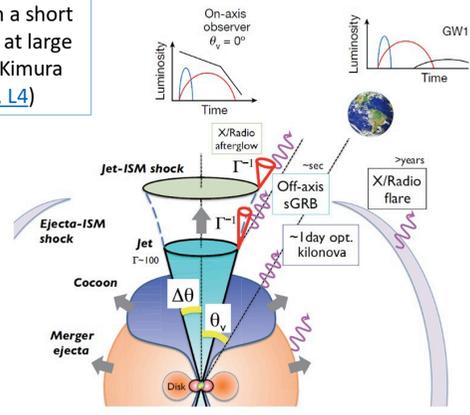
From my rapporteur
talk at ICRC 2025

Point-source MM
connections will be discussed
by Giulia Illuminati in the next talk



Non-detection:
consistent with a short
GRB observed at large
off-axis angle (Kimura
et al. [ApJL 848, L4](#))

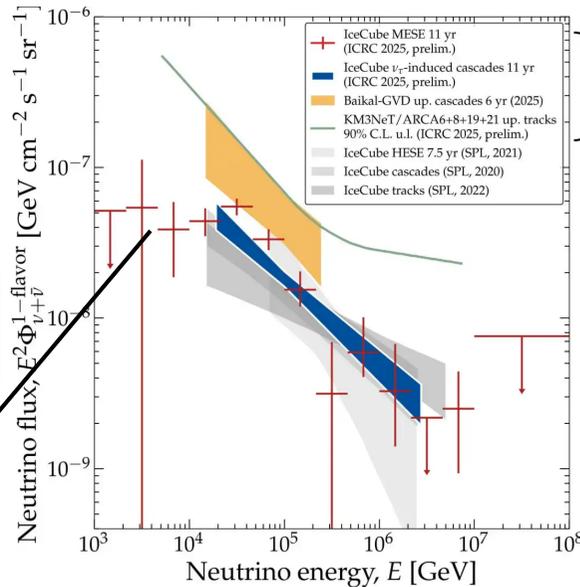
No detection during extended time period of 14 days
after the GRB (Fang & Metzger, [ApJ 849 153](#))



The importance of MM study of accelerator classes

From Bustamante
rapporteur talk
at ICRC 2025

And IceCube is
finding structure
in the energy
spectrum



The three existing
large neutrino
telescopes are
independently
probing the diffuse
flux of TeV–PeV
cosmic ν !

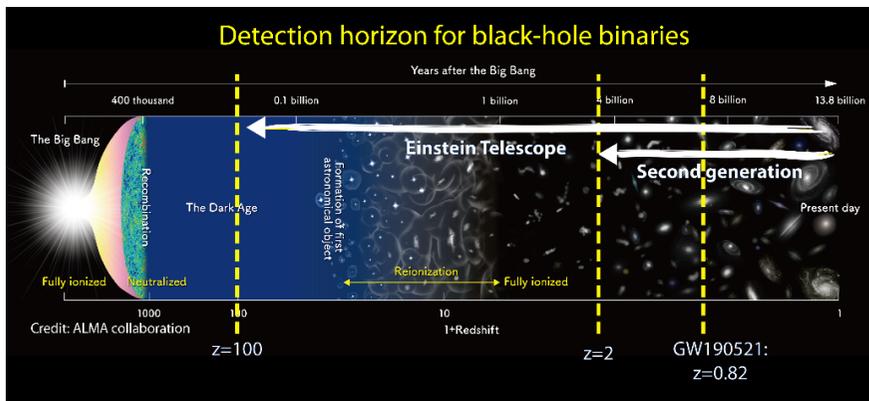
Thanks to
Aswathi Balagopal
for providing the
butterflies!

We cannot ignore hundred of
astrophysical neutrinos because they
don't have a counterpart.
Neutrino astronomy means
also understanding the characteristics of
of cosmic accelerator populations

30

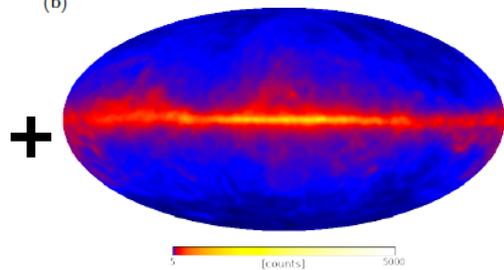
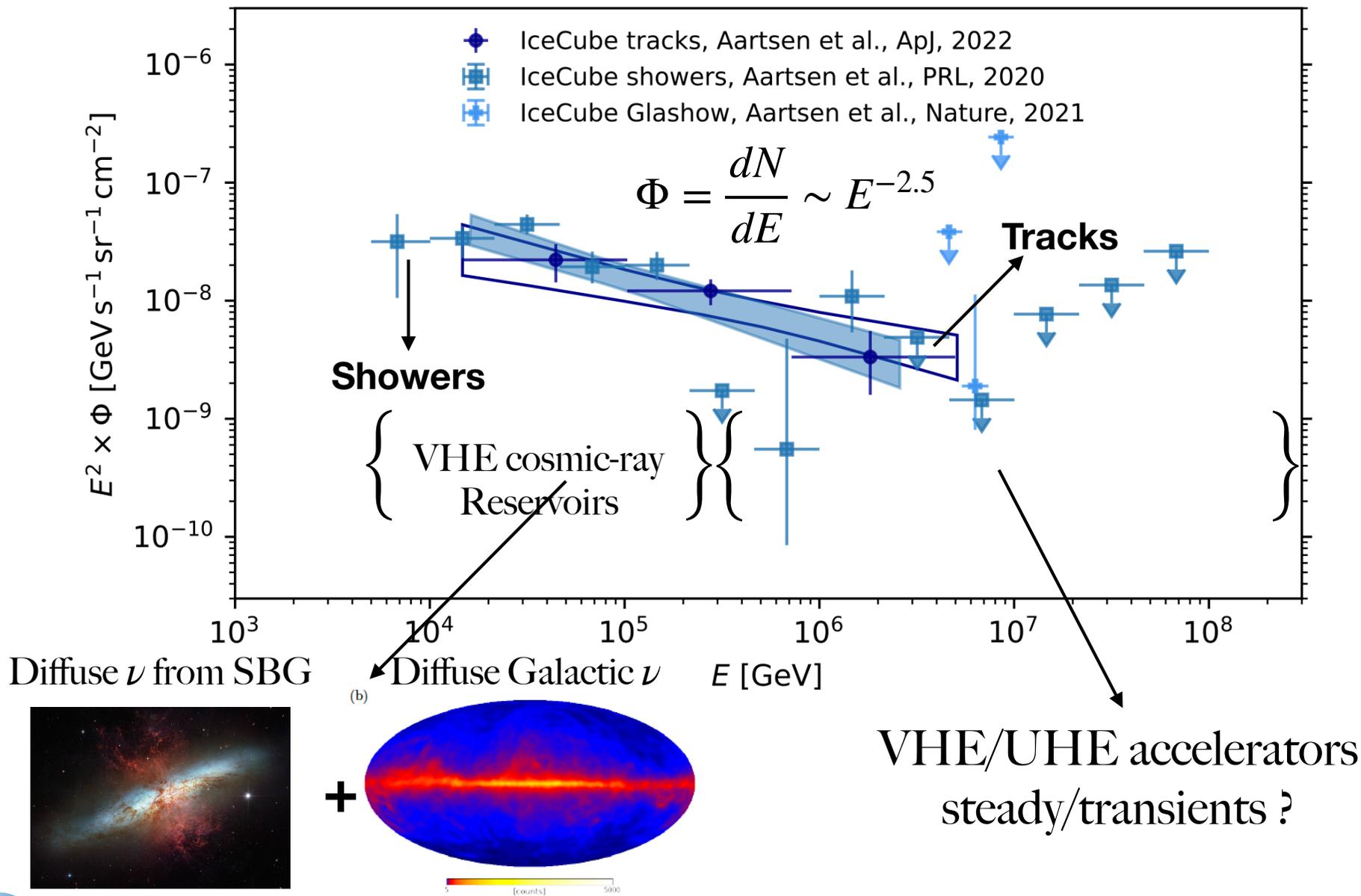
Break at low
energy confirmed
also by Antares

ANTARES
coll
JCAP 2024



With new electromagnetic surveys + the
arrival of ET we will explore deeper portions
of our Universe making the populations study
crucial for neutrino astronomy

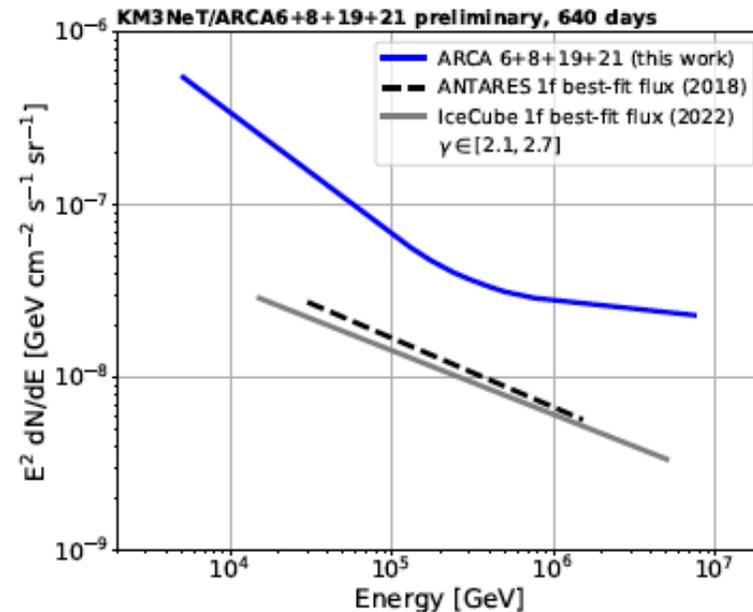
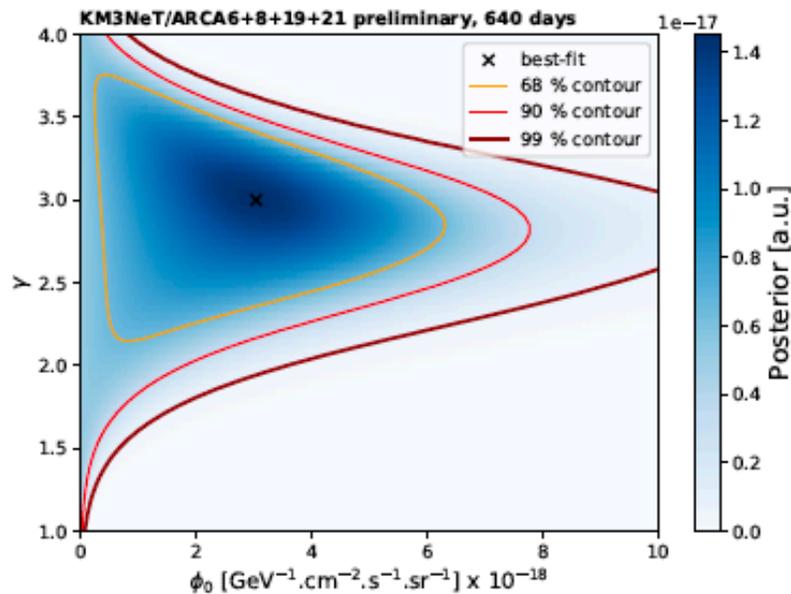
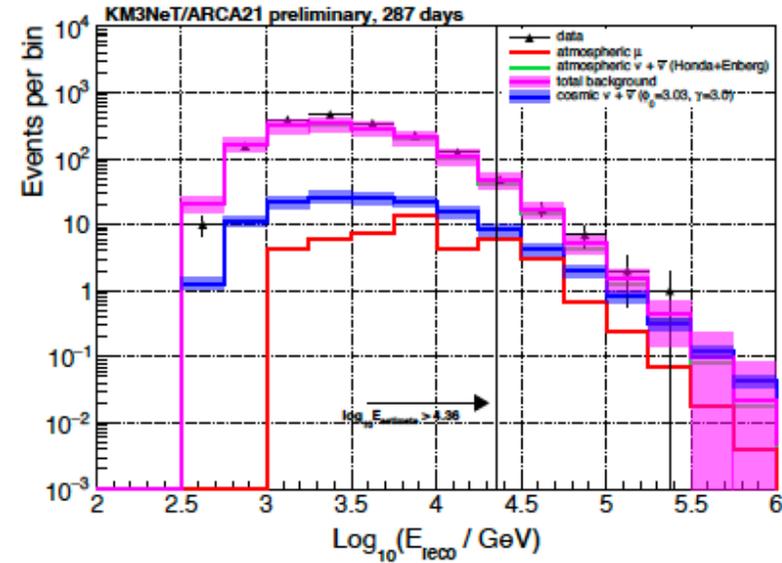
Setting the ν multicomponent energy ranges



KM₃NeT full sky diffuse ν studies

V.Tsourapis
PoS 1192 ICRC 2025

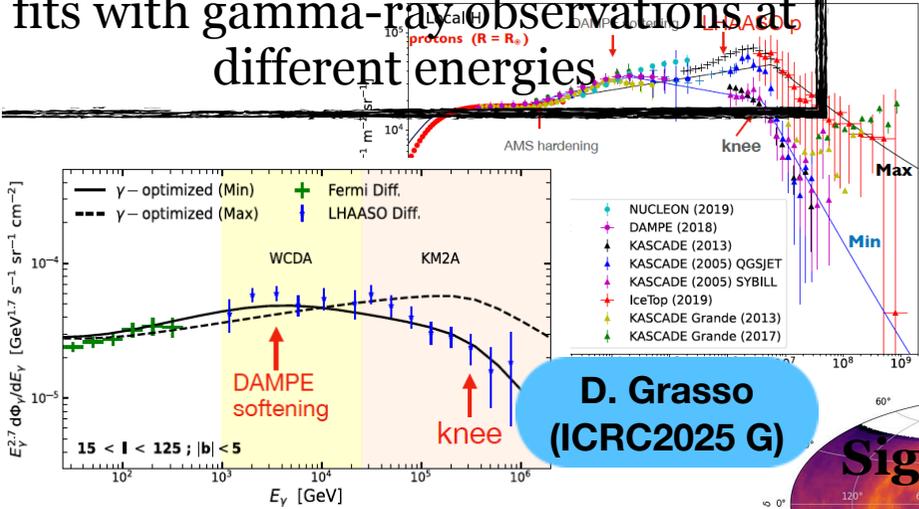
A binned Likelihood bayesian analysis has been performed closing the 1 sigma region of the 2D parameter space, γ and ϕ_0 with the data of ARCA 6-21



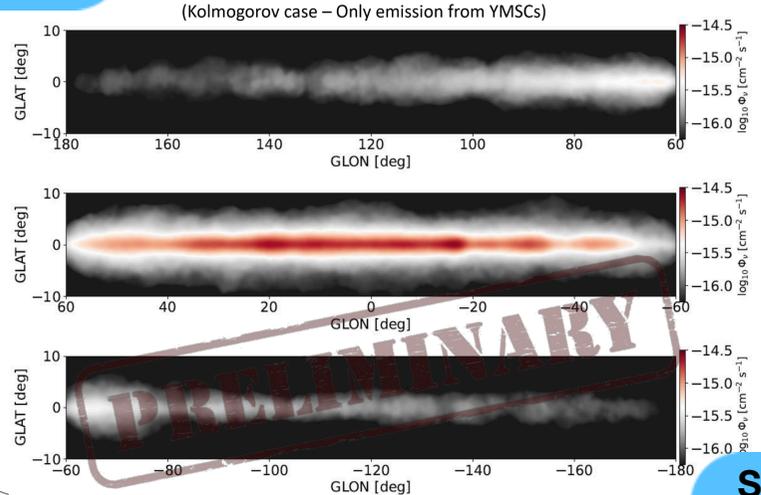
Multimessenger diffuse Galactic emission

Model templates based on CR transport and interaction with gas fits with gamma-ray observations at different energies

From my rapporteur talk at ICRC 2025

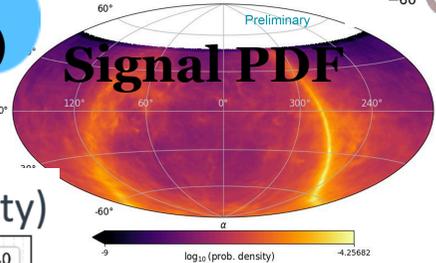


D. Grasso (ICRC2025 G)



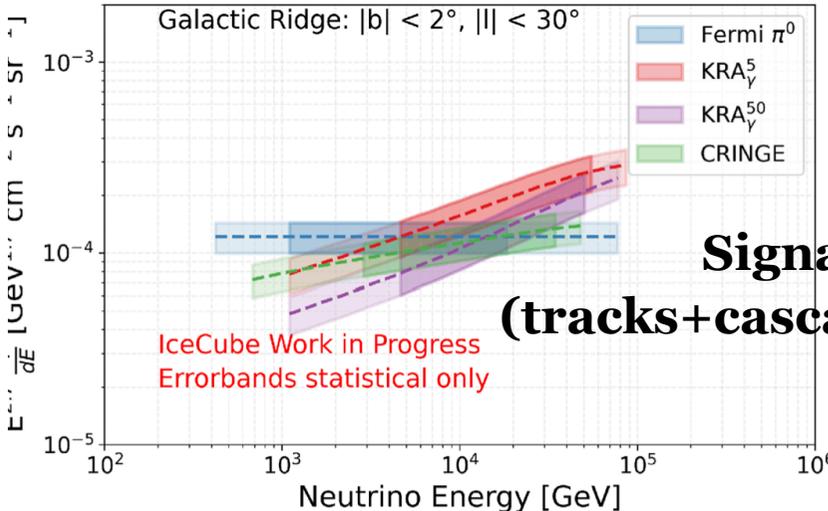
Integrated all flavor neutrino emission (E>1 TeV)
A public template of the expected neutrino emission will be published
Median emission obtained from 100 different realizations of the Milky Way

S. Celli et al (ICRC2025 G)



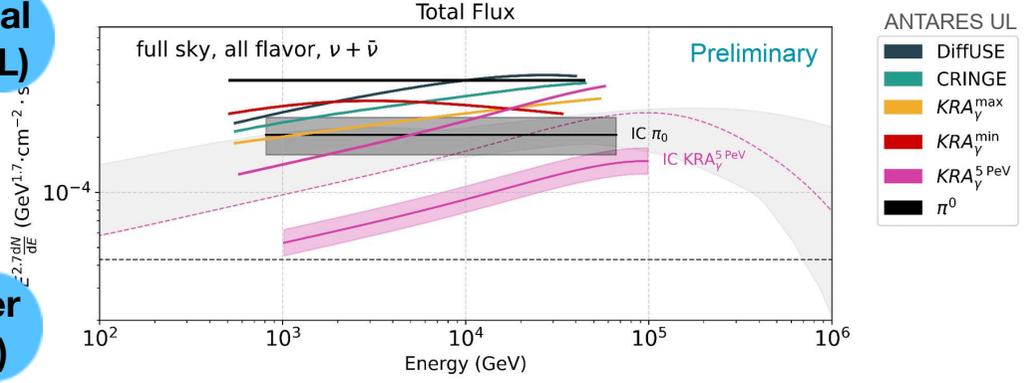
T. Cartraud (ICRC2025 N)

Galactic center region (highest sensitivity)



A.Kappes et al (ICRC2025 PL)

M. Thiesmeyer (ICRC2025 N)



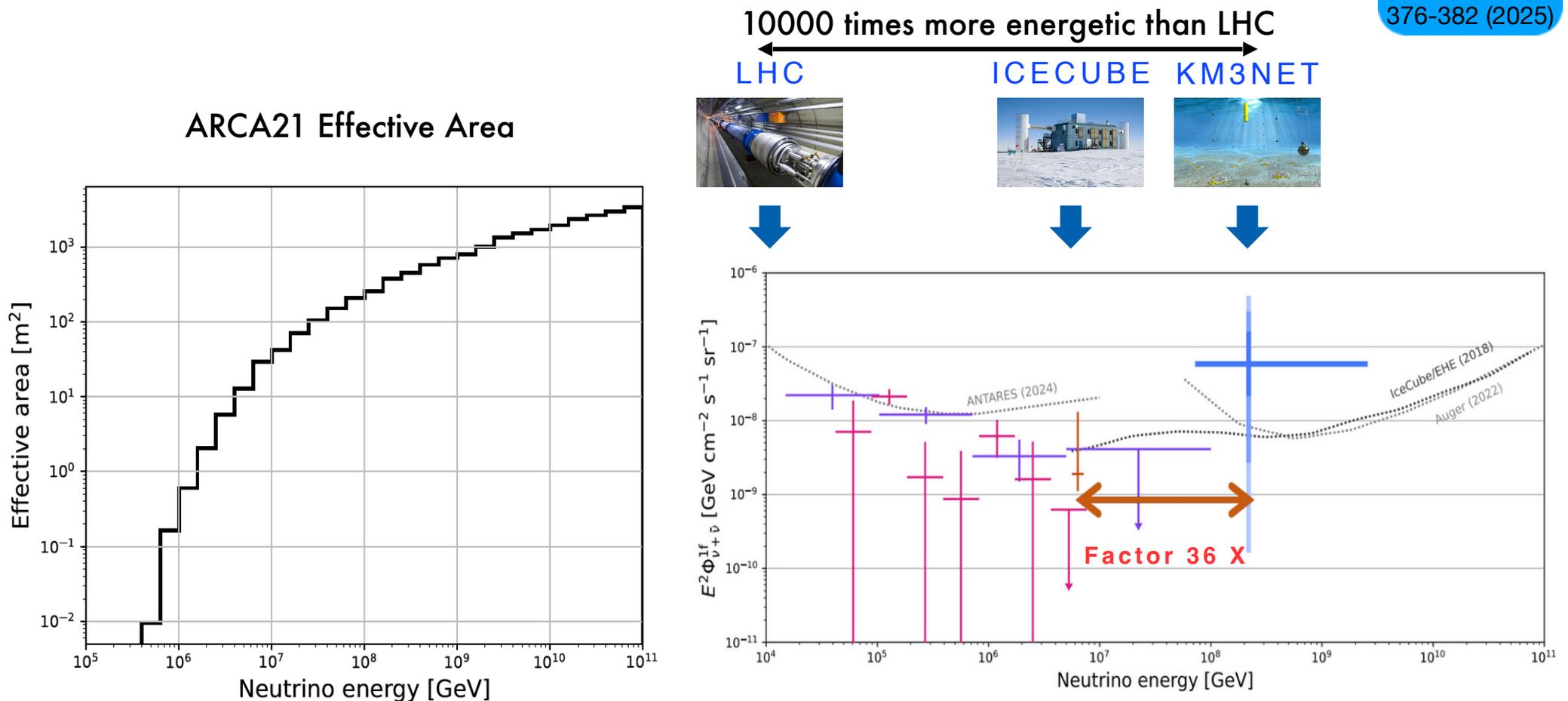
Model Predictions: range of the different model predictions (except π_0)



The detection of KM3-230213A

On the left we reported the Effective Area obtained using the quality cuts used for the Selection of KM3-230213A, on the right the equivalent diffuse flux needed to produce one event with the time of data taking of ARCA19/21

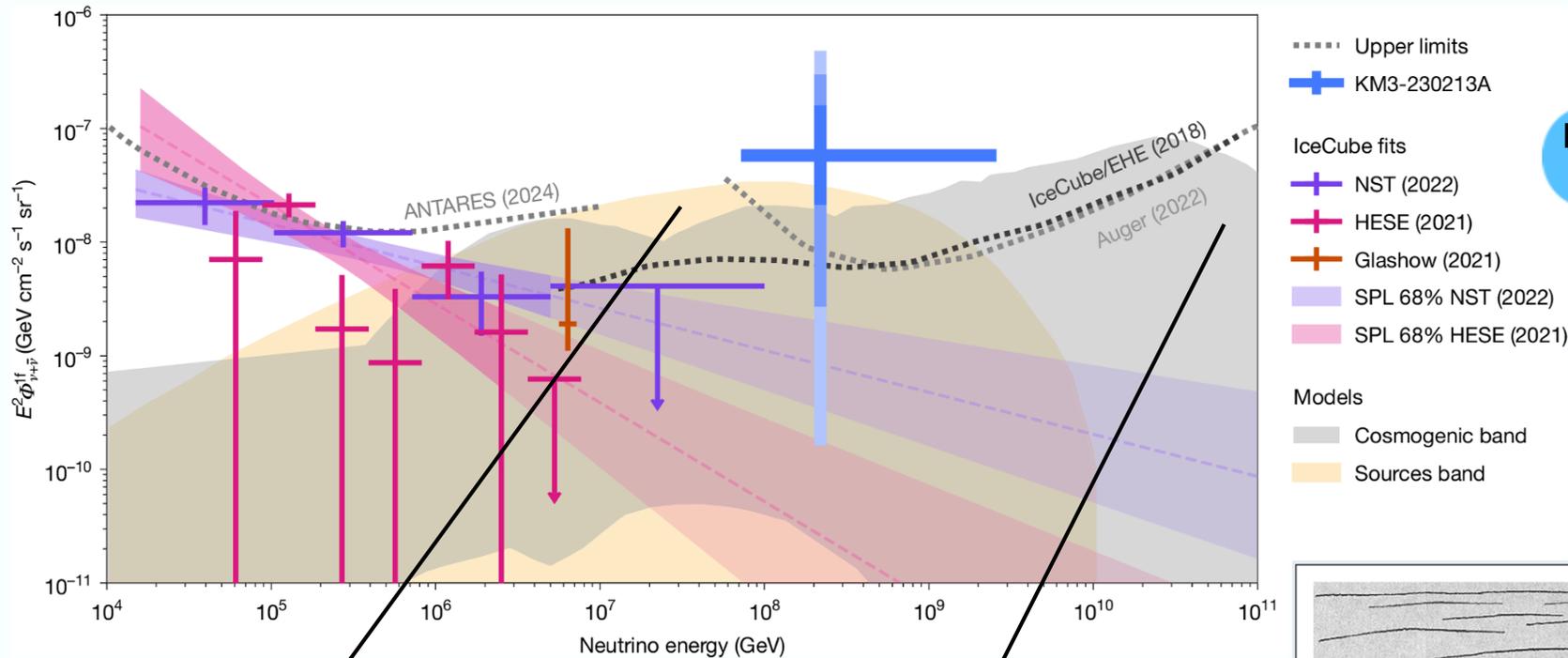
KM3NeT coll.
Nature 638,
376-382 (2025)



The first UHE neutrino - MM perspectives

KM3NeT coll.
Nature 638,
376-382 (2025)

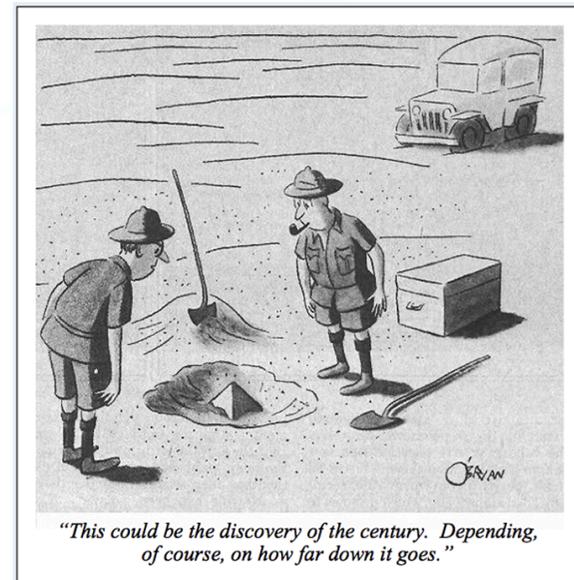
From my rapporteur
talk at ICRC 2025



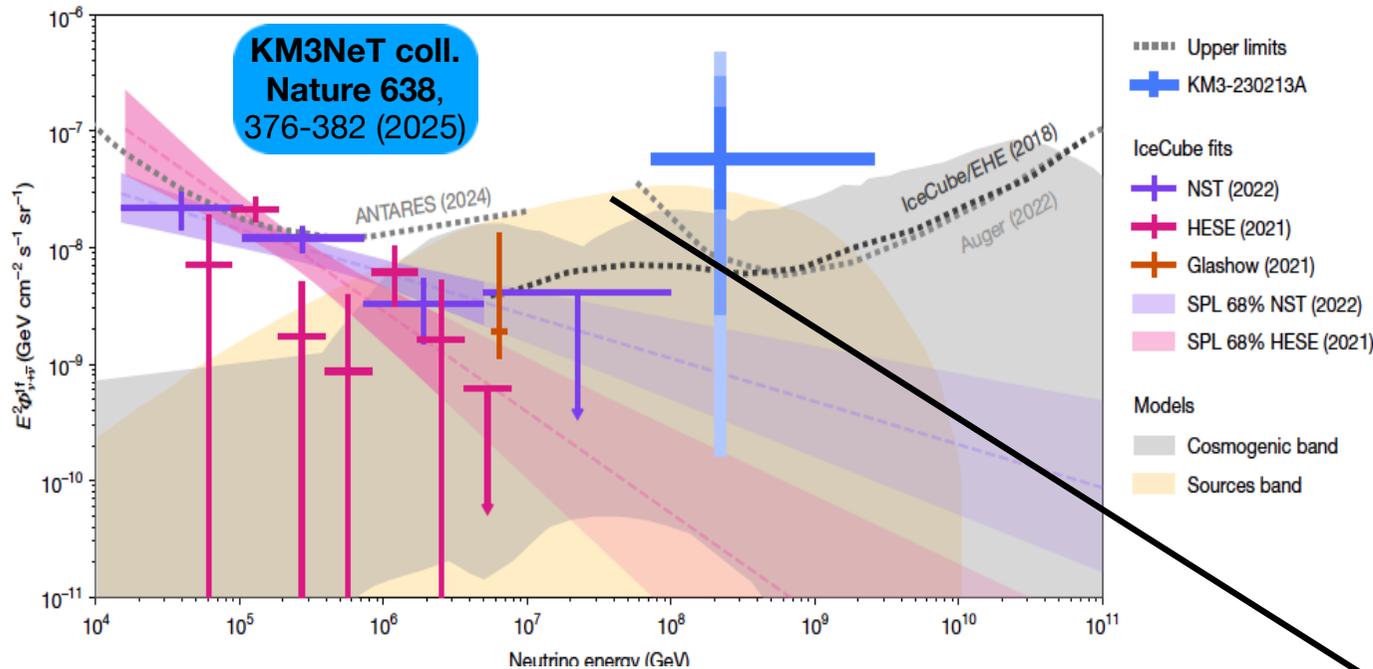
Diffuse extragalactic
MM with EM needed
(Sources population
Characteristics)

Extragalactic source
MM with EM needed
(Variable, stable emission.
Type of source)

Cosmogenic
MM with UHE CR &
EM needed
- UHECR composition.
- Sources evolution.



The diffuse extragalactic hypothesis



The vanilla band represents different classes of extragalactic objects, mostly variable and transients as Blazars, GRBs, TDEs with luminosity between 10^{44} to 10^{54} erg/s

These neutrinos are mostly produced through the photohadronic processes when accelerated cosmic rays interact with thermal or leptonic emitted photons.

Event rate expected in ARCA21 for different diffuse flux cases.

Tested flux	Expected events in ARCA19-21 in full energy range in 72 PeV – 2.6 EeV	
	Source (transient) diffuse models	
Pulsar (Fang. et al [43])	1.3	0.47
LL-BLLacs (Rodrigues et al. [45])	0.56	0.26
TDE (Winter et al. [39])	0.42	5.5×10^{-2}
LL-GRBs (Boncioli et al. [34])	0.15	2.5×10^{-3}
Sample FSRQ (Rodrigues et al. [46])	1.2×10^{-2}	4.6×10^{-5}
LL-GRB (Tamborra et al. [41])	1.0×10^{-2}	5.9×10^{-4}
Sample LL-BLLac (Rodrigues et al. [46])	5.0×10^{-3}	3.3×10^{-6}
s-GRB (Tamborra et al. [41])	2.8×10^{-6}	6.6×10^{-7}

The diffuse blazar population hypothesis

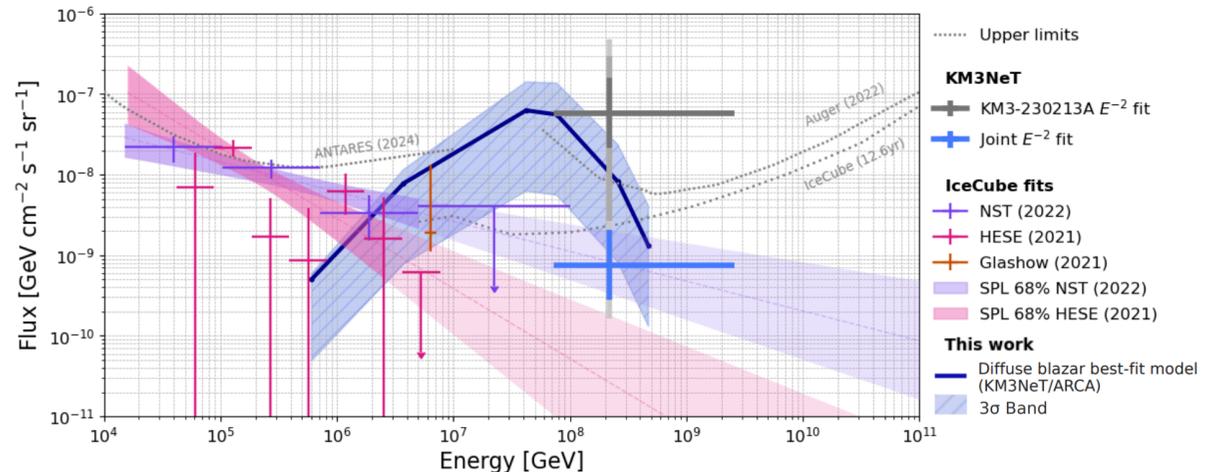
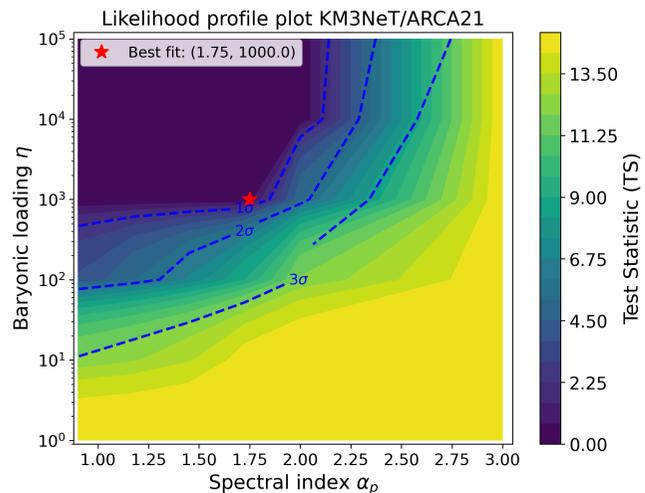
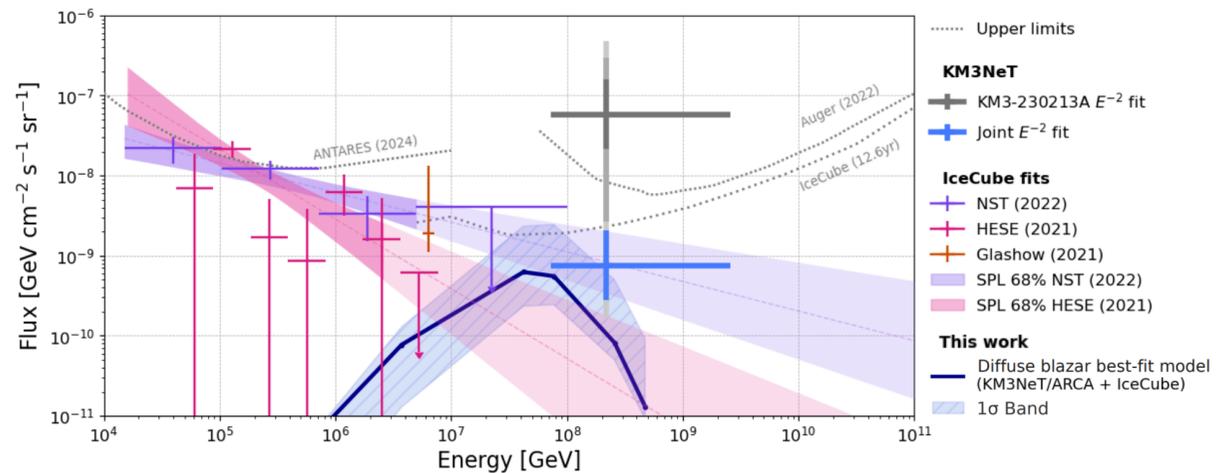
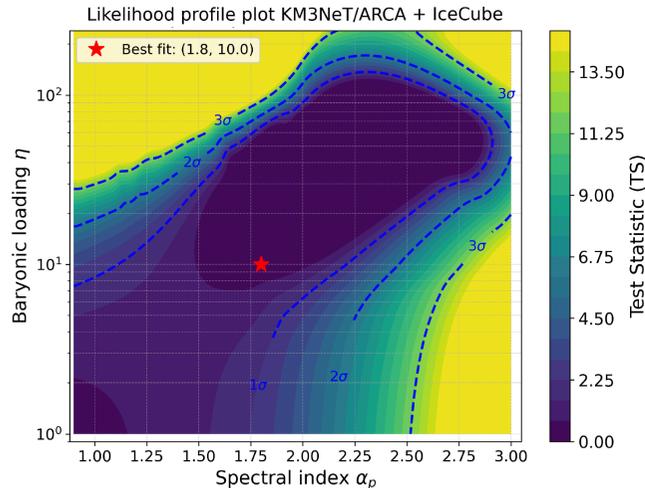
A statistical analysis has been performed to see under which hypotheses the KM3-230213A

KM3NeT coll.
arXiv 2511.13886

event can be compatible with a population of luminous BL-Lacs

Rodrigues et al.
A&A 2024

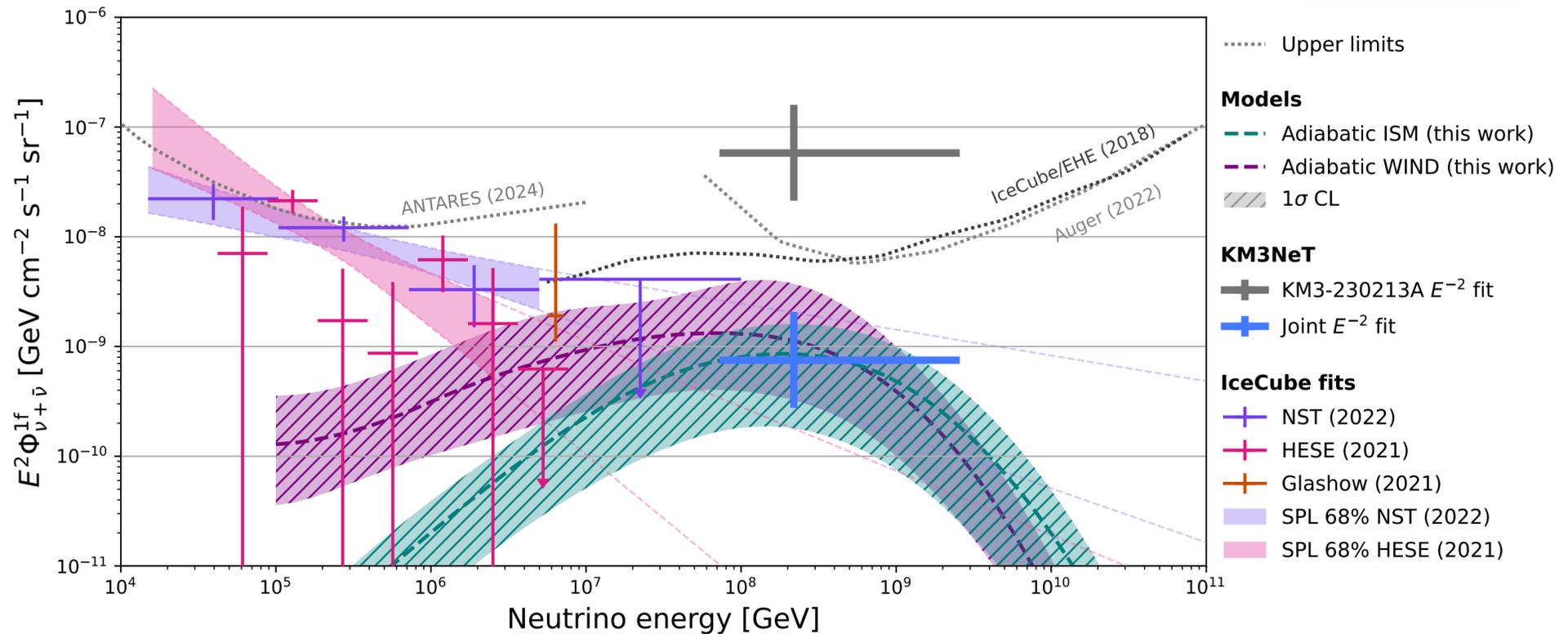
AM3 code has been used to fix the parameters, and obtain the neutrino flux integrating up $z=6$



The diffuse GRBs population hypothesis

Similar analysis has been obtained by considering the diffuse GRBs blast wave emission, integrating the possible neutrino emission up $z=5$

KM3NeT coll.
arXiv 2509.14895



However recent IceCube stacking analysis pose a upper limit on the diffuse astrophysical flux Related to prompt GRBs emission at the level of 1%

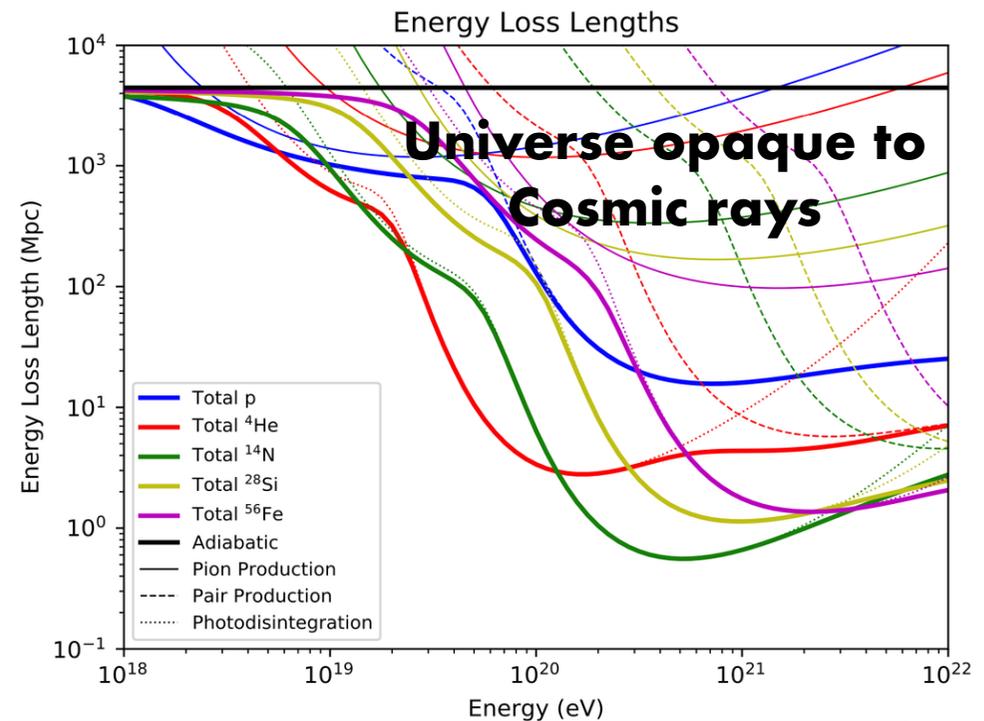
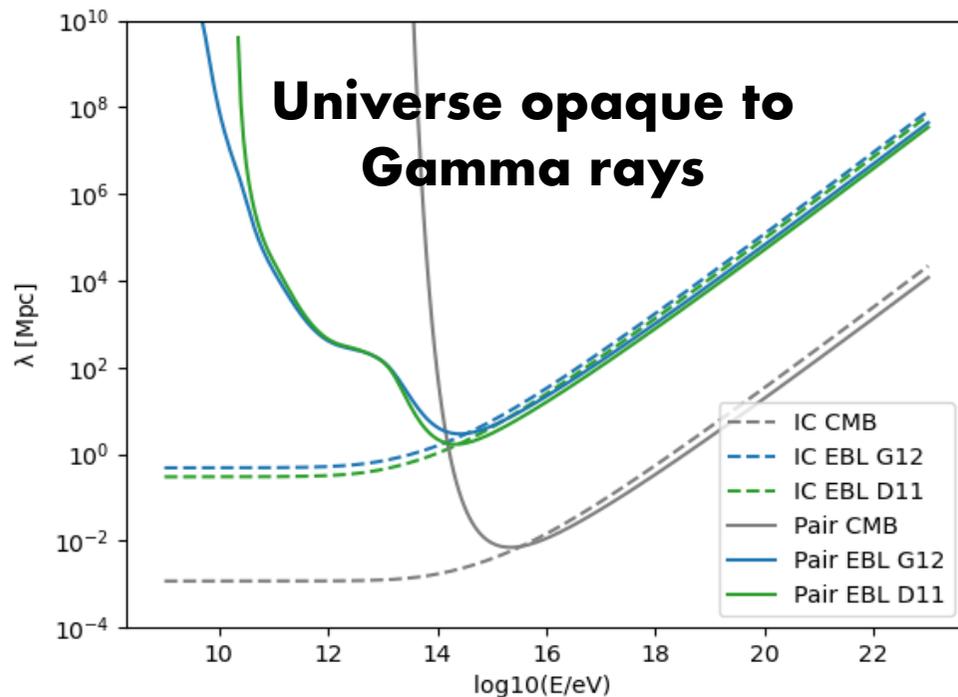
IceCube coll.
APJ 939:116, 2022



The deep universe observed through the ν

For the observed energy we can make the hypothesis to explore of the Universe never explored before, or in other words the most faraway accelerators observed for such energies

KM3NeT coll.
APJL 984:L41, 2025



EM survey of transient powerful events from the deep Universe can have a unique link with the UHE neutrino events

Cosmological model used for the paper

KM3NeT coll.
APJL 984:L41, 2025

- ▶ Cosmological framework to compute neutrino fluxes produced in EG propagation;
- ▶ Assume that each source is identical and distributed with a given evolution m

$$\frac{dN}{dE} \propto f_A \left(\frac{E}{10^{18} \text{eV}} \right)^{-\gamma} \times f_{cut}(E, Z_A, R_{cut}) \times (1+z)^m$$
- ▶ Fit to UHECR data \rightarrow normalization to neutrino flux.
- ▶ Important parameters to fix : m and z . All the others are fitted to describe UHECR data.

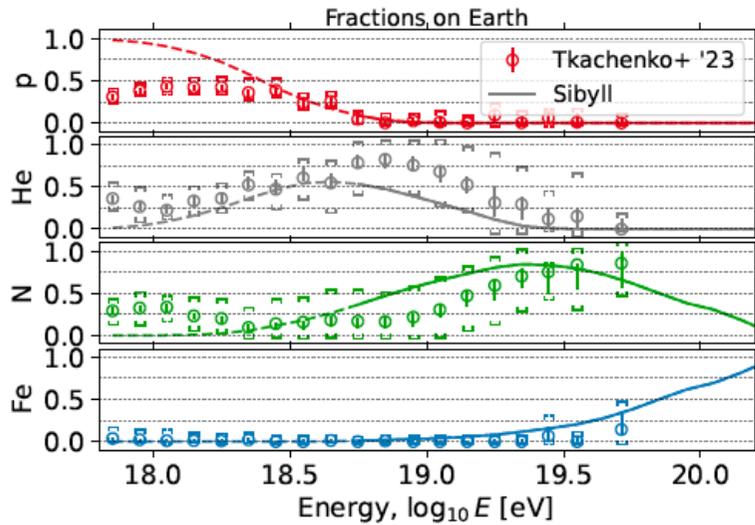


Emission rate density Comoving source density Injection term source type

$$L(E, z) = S(z) \times Q_{CR}(E)$$

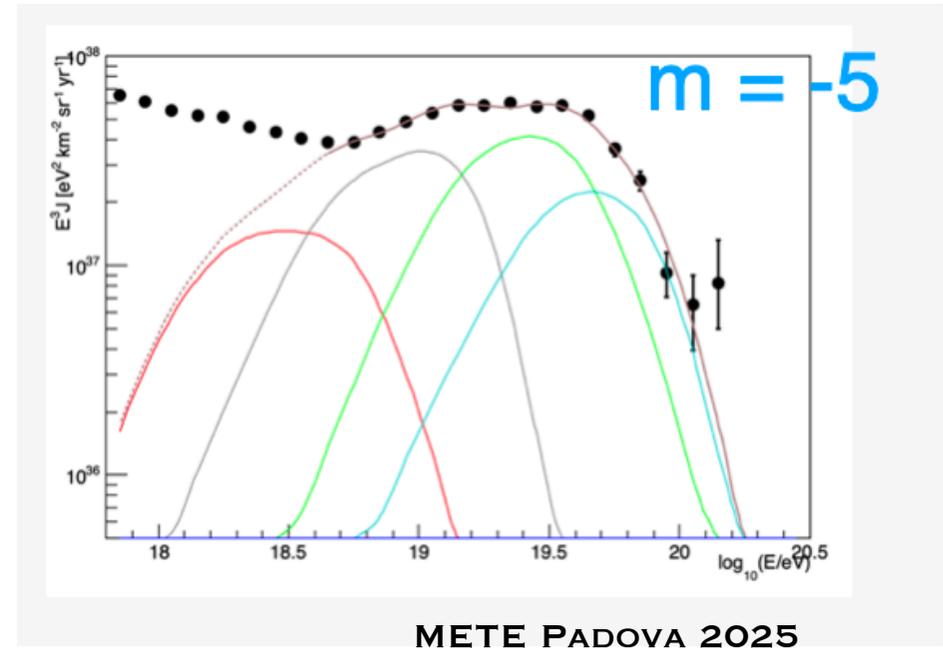
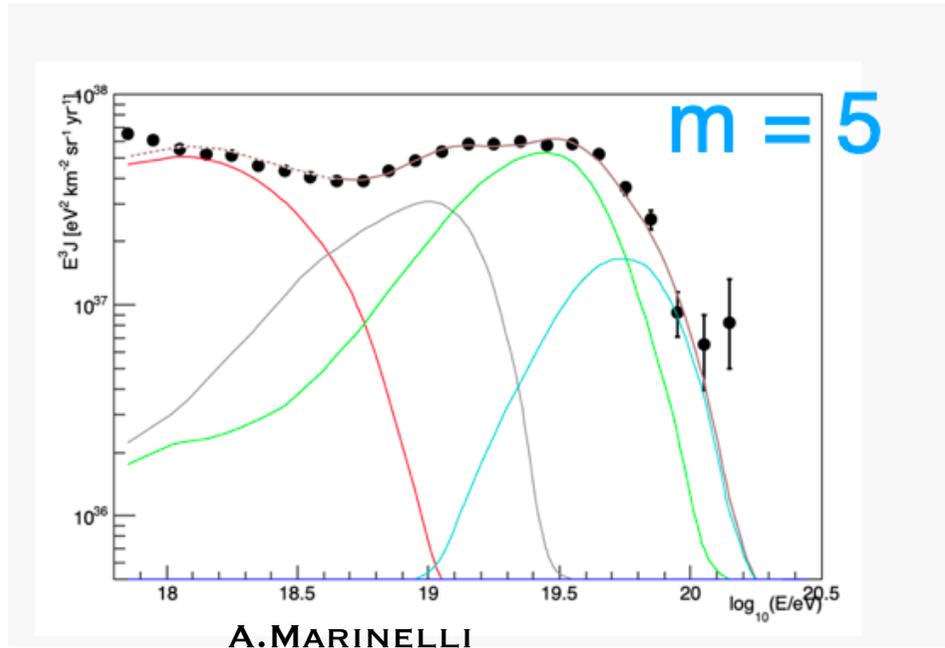
Fitting cosmic-ray data with different evolution parameter m

KM3NeT coll.
APJL 984:L41, 2025



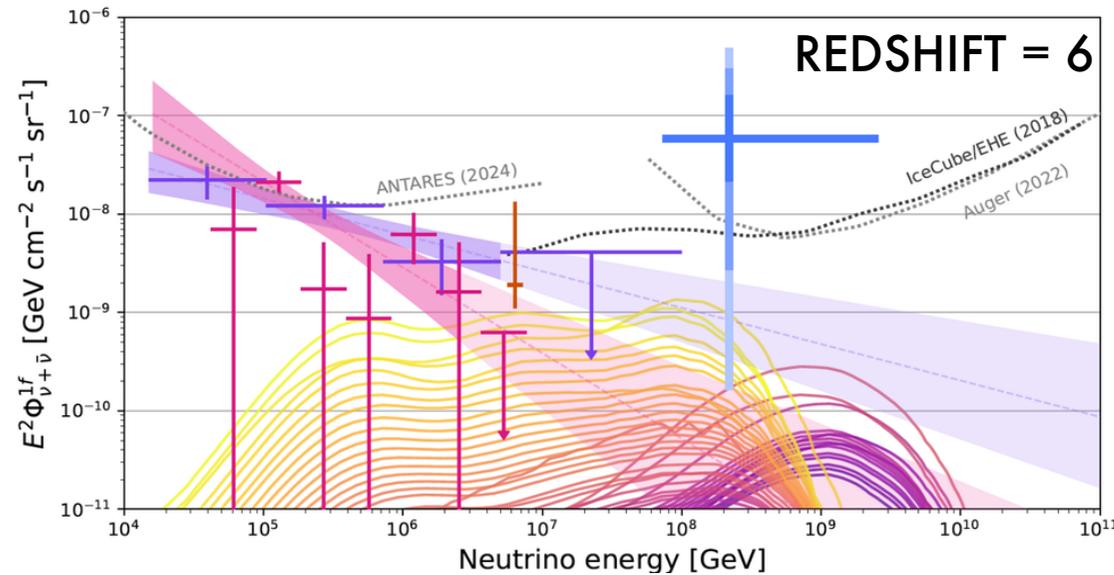
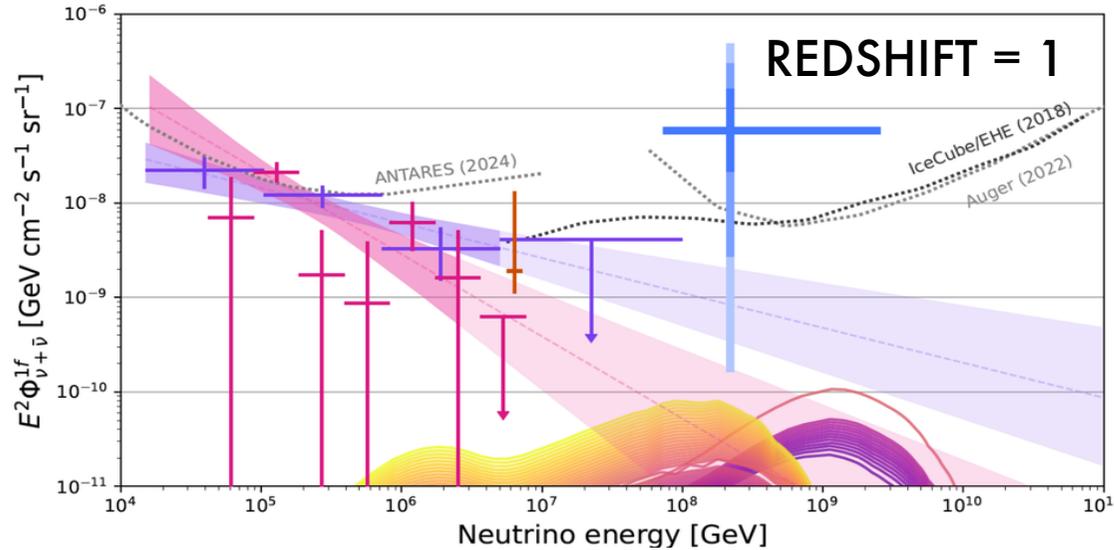
- High $m \sim 5$ \longrightarrow High luminosity sources
- Intermediate $m \sim 3$ \longrightarrow Star formation evolution
- $m \sim 0$ \longrightarrow Stellar mass density
- Negative $m \sim -3-5$ \longrightarrow LL BL-Lac. Radio galaxies

$$S(z) \propto (1 + z)^m$$



Possible cosmogenic origin of KM3-230213A

KM3NeT coll.
APJL 984:L41, 2025



To be slightly consistent with the equivalent flux of the UHE ν event, we need to integrate The cosmogenic component up to higher Redshifts

We can be compatible with the most distant Cosmic accelerators ever seen

In this range of energy

SUMMARY

- From 2013 a lot of “orphan” astrophysical neutrinos has been collected.
- Even though the next MM breakthrough can come for the nearby Universe population studies are crucial for neutrino astronomy.
- Incoming EM surveys + the arrival of ET, LISA will represent a unique opportunity to explore the deep powerful Universe.
- The population studies should be synergetic to single sources MM observations, new tensions can tell us more infos about the physics at the source.
- KM₃NeT/ARCA can obtain soon a first full sky VHE neutrino excess.
- KM₃-230213A pave the way for the searching to sources following strong evolution scenarios.